



US009449631B2

(12) **United States Patent**
Gong et al.

(10) **Patent No.:** **US 9,449,631 B2**
(45) **Date of Patent:** **Sep. 20, 2016**

(54) **SLIDER FOR MAGNETIC RECORDING SYSTEM**

(71) Applicant: **Western Digital Technologies, Inc.**,
Irvine, CA (US)

(72) Inventors: **Yongping Gong**, Eagan, MN (US);
Phuwanai Bunnak, Ladsawai (TH);
Kah Choong Loo, Pakkret (TH);
Krisda Siangchaew, Ta Sai (TH)

(73) Assignee: **WESTERN DIGITAL TECHNOLOGIES, INC.**, Irvine, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/809,775**

(22) Filed: **Jul. 27, 2015**

(65) **Prior Publication Data**

US 2015/0332720 A1 Nov. 19, 2015

Related U.S. Application Data

(62) Division of application No. 13/797,069, filed on Mar. 12, 2013, now Pat. No. 9,093,102.

(51) **Int. Cl.**

G11B 5/127 (2006.01)

H04R 31/00 (2006.01)

G11B 5/60 (2006.01)

G11B 5/851 (2006.01)

(Continued)

(52) **U.S. Cl.**

CPC **G11B 5/6082** (2013.01); **G11B 5/732** (2013.01); **G11B 5/84** (2013.01); **G11B 5/8404** (2013.01); **G11B 5/851** (2013.01); **Y10T 29/49705** (2015.01)

(58) **Field of Classification Search**

CPC Y10T 428/30; Y10T 29/49705; G11B 5/732; G11B 5/6082; G11B 5/8408; G11B 7/26; C23C 14/0611; H01F 41/183; B01J 2203/062; B01J 2203/0655
USPC 29/603.07, 603.01, 603.03, 603.12, 29/603.14; 427/128, 131, 251, 255.5
See application file for complete search history.

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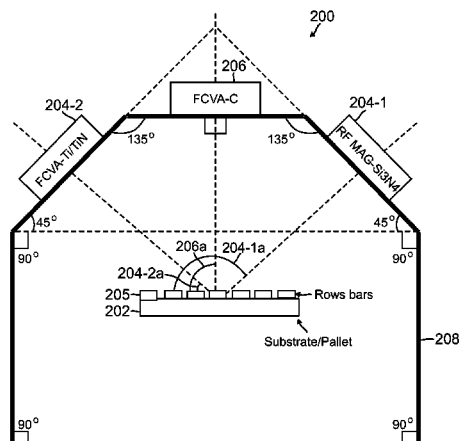
(74) *Attorney, Agent, or Firm* — Gabriel Fitch; Loza & Loza, LLP

(57)

ABSTRACT

Systems and methods for tuning seed layer hardness in components of magnetic recording systems are described. One such system includes a substrate including a component configured to deposit a seed layer material on a portion of a top surface of the substrate at a first angle, and a second deposition source configured to deposit a carbon material including sp³ carbon bonds on the portion of the top surface at a second angle not equal to the first angle, where the first deposition source and the second deposition source deposit the seed layer material and the carbon material, respectively, simultaneously. The component can be a slider or a magnetic medium.

6 Claims, 5 Drawing Sheets



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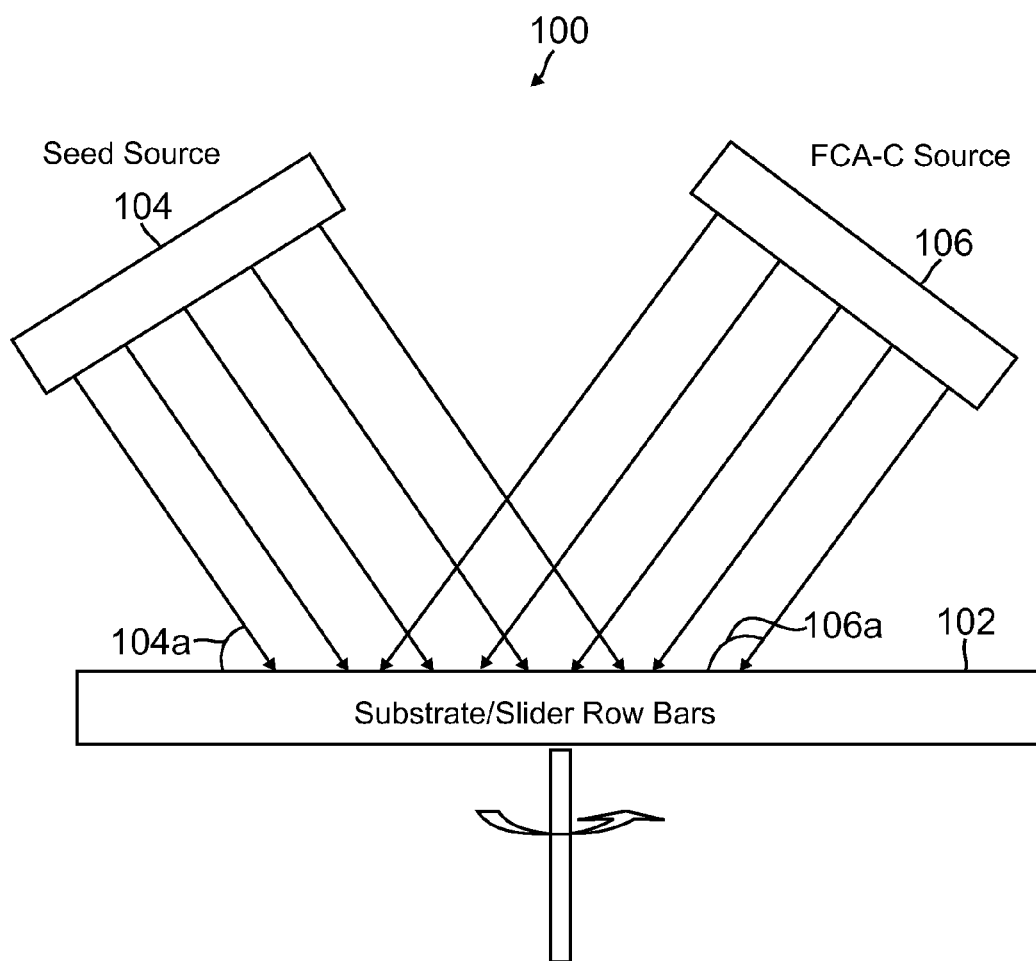


FIG. 1

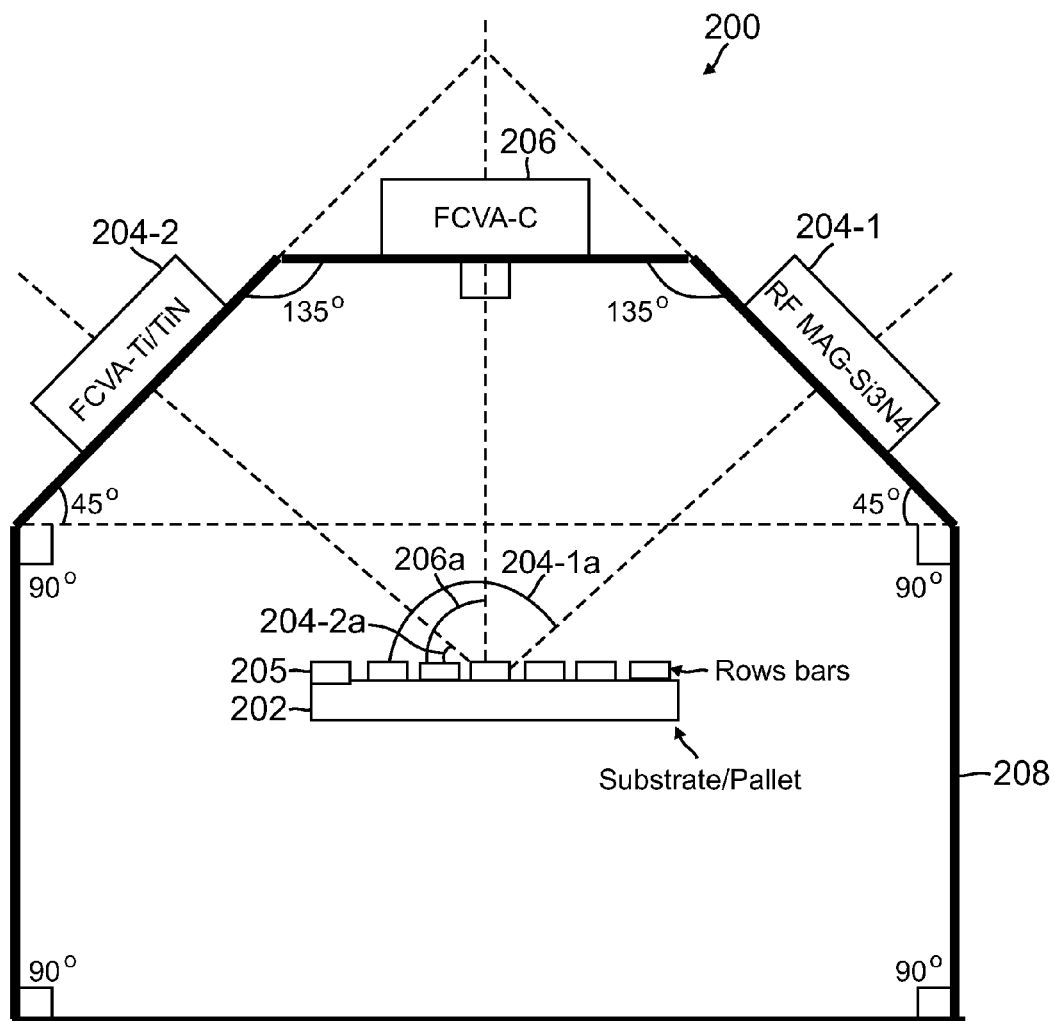


FIG. 2

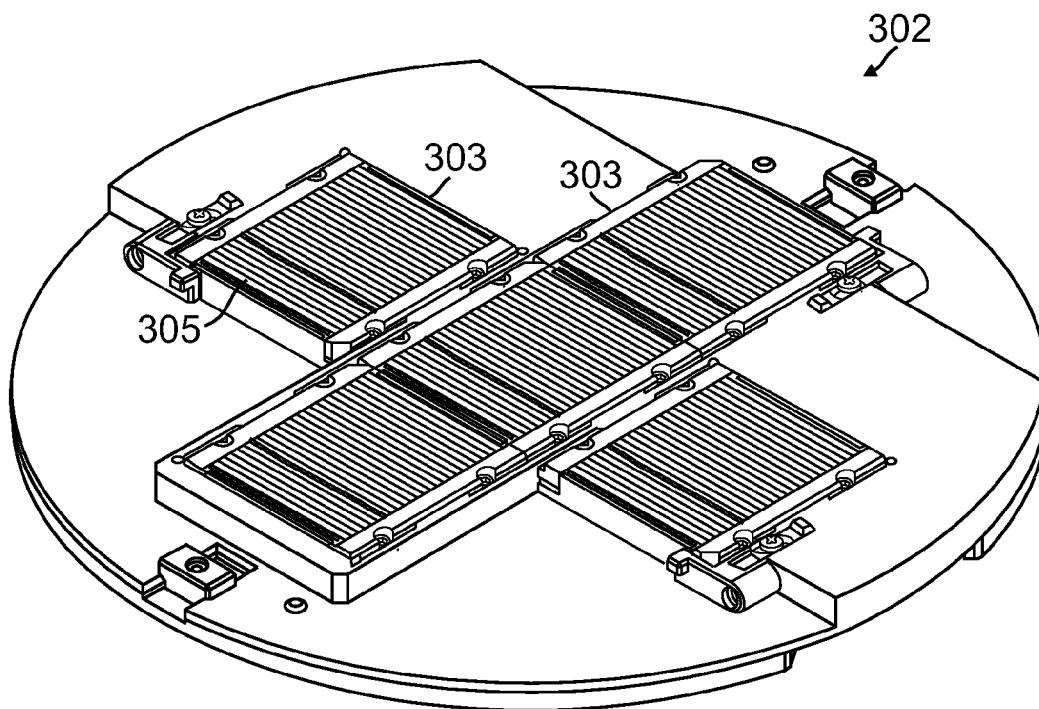


FIG. 3

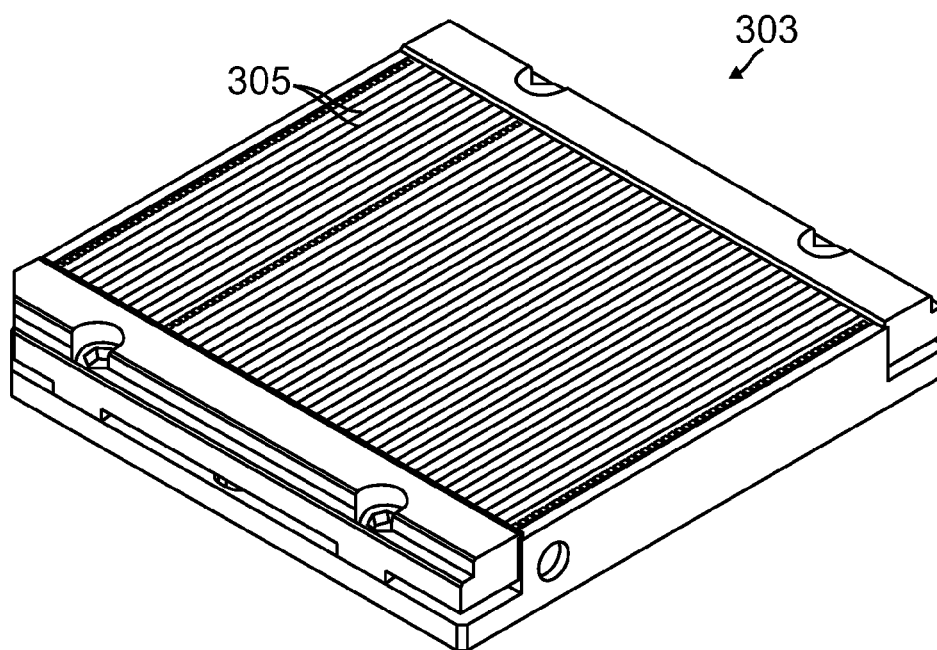


FIG. 4

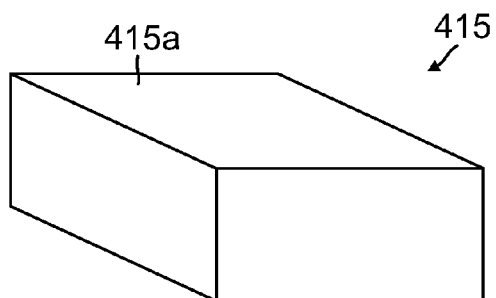


FIG. 5

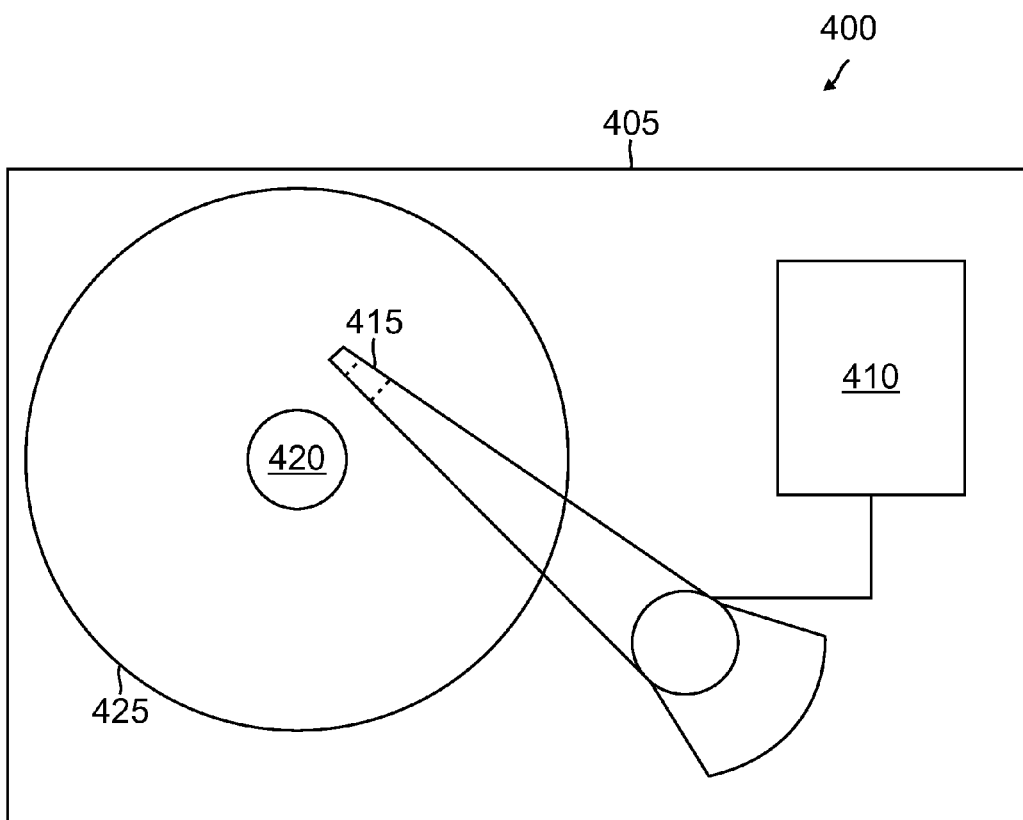


FIG. 6

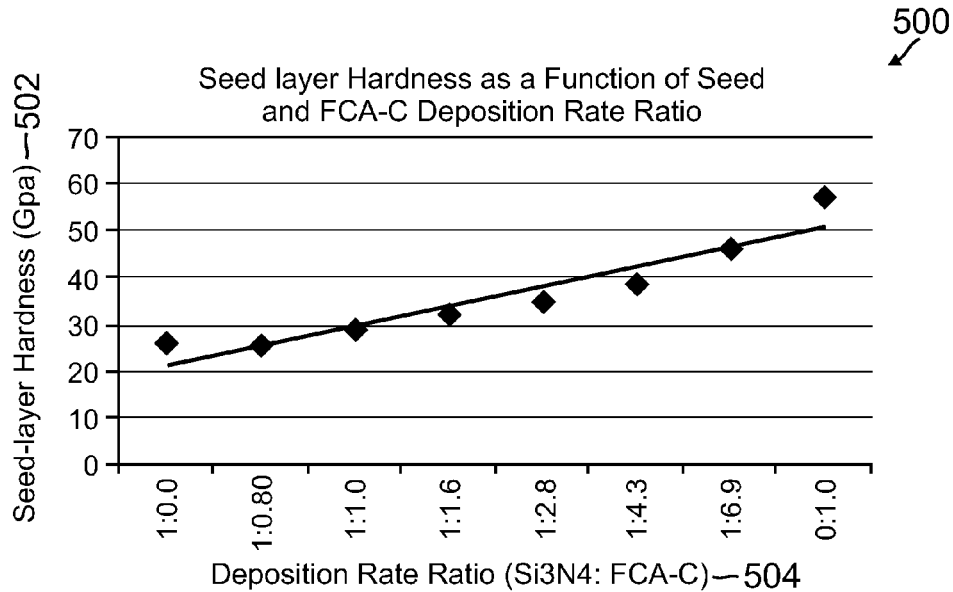


FIG. 7

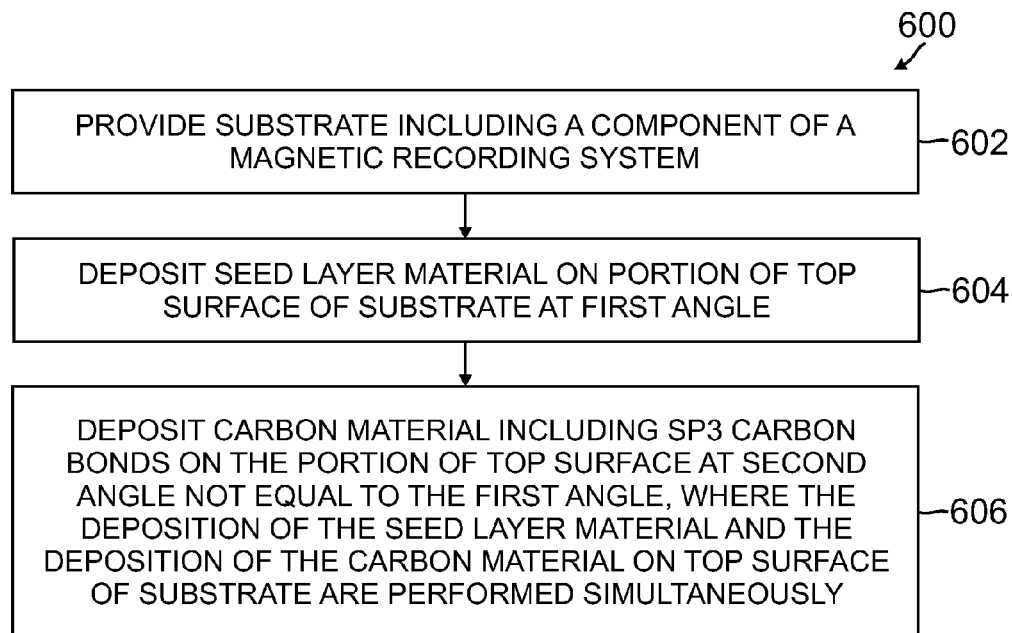


FIG. 8

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SLIDER FOR MAGNETIC RECORDING SYSTEM

CROSS REFERENCE TO RELATED APPLICATION

This application is a divisional of U.S. patent application Ser. No. 13/797,069, filed on Mar. 12, 2013, which is hereby incorporated by reference in its entirety.

FIELD

The present invention relates generally to magnetic recording systems, and more specifically to systems and methods for tuning seed layer hardness in components of magnetic recording systems.

BACKGROUND

One application of magnetic recording is hard disk drives. It is well known in the hard disk drive industry that a head over-coat (HOC) film is deposited on the ABS of a read-write head (e.g., such as the read-write head of a slider) to provide corrosion and wear resistance to the device. The traditional HOC film has a bi-layer structure, where a seed layer is deposited onto the device substrate first, followed by carbon film deposition. The seed layer deposition may be achieved by ion beam or magnetron sputtering deposition technologies. In both cases, seed layer material is sputtered off of a target by energetic Ar ions onto the substrate where the sliders are populated. The carbon film deposition employs filtered cathodic arc (FCA) technology.

Over the years, the seed layer material has evolved from pure Si to various mixtures of materials including Si. This is motivated by improved corrosion and wear resistance that derives from a harder and denser seed layer, which enables a reduction in the overall thickness of the HOC film. A thinner HOC film translates to narrower head to media spacing (HMS), and enhances electro-magnetic performance of the read-write head. However, the space for performance improvement from the traditional seed layer is limited by strength of selected seed layer bonds and their packing densities.

SUMMARY

Aspects of the invention relate to systems and methods for tuning seed layer hardness in components of magnetic recording systems. In one embodiment, the invention relates to a method for tuning a seed layer hardness in components of a magnetic recording system, the method including providing a substrate including a component of a magnetic recording system, depositing a seed layer material on a portion of a top surface of the substrate at a first angle, and depositing a carbon material including sp³ carbon bonds on the portion of the top surface at a second angle not equal to the first angle, where the depositing the seed layer material and the depositing the carbon material on the top surface of the substrate are performed simultaneously.

In another embodiment, the invention relates to a system for tuning a seed layer hardness in components of a magnetic recording system, the system including a substrate including a component of a magnetic recording system, a first deposition source configured to deposit a seed layer material on a portion of a top surface of the substrate at a first angle, and a second deposition source configured to deposit a carbon material including sp³ carbon bonds on the portion of the top

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surface at a second angle not equal to the first angle, where the first deposition source and the second deposition source deposit the seed layer material and the carbon material, respectively, simultaneously.

In yet another embodiment, the invention relates to a slider for a magnetic recording system, the slider including an air bearing surface (ABS) including a seed layer deposited using a co-deposition process including deposition of a seed layer material on the ABS at a first angle and deposition of a carbon material including sp³ carbon bonds on the ABS at a second angle not equal to the first angle, where the deposition of the seed layer material and the deposition of the carbon material are performed simultaneously, and where the seed layer includes a preselected number of the sp³ carbon bonds.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic top view of a two source vacuum deposition system for tuning the seed layer hardness of sliders arranged in row bars on a rotatable substrate/pallet in accordance with one embodiment of the invention.

FIG. 2 is a schematic top view of a three source vacuum deposition system for tuning the seed layer hardness of sliders arranged in row bars on a rotatable substrate/pallet in accordance with one embodiment of the invention.

FIG. 3 is a perspective view of a rotatable substrate/pallet with multiple row bar carriers that can be used in the vacuum deposition systems of FIG. 1 or FIG. 2.

FIG. 4 is an expanded perspective view of a row bar carrier of the rotatable substrate/pallet of FIG. 3.

FIG. 5 is a schematic perspective view of a slider with a seed layer having been deposited along an air bearing surface thereof using a co-deposition system having both a seed layer material source and a carbon material source in accordance with one embodiment of the invention.

FIG. 6 is a top schematic view of a disk drive including the slider of FIG. 5 in accordance with one embodiment of the invention.

FIG. 7 is a graph of seed layer hardness versus a deposition rate ratio of the seed layer material deposition rate to the carbon material deposition rate in accordance with one embodiment of the invention.

FIG. 8 is a flowchart of a co-deposition process for tuning seed layer hardness in components of a magnetic recording system such as a slider or a magnetic medium in accordance with one embodiment of the invention.

DETAILED DESCRIPTION

Referring now to the drawings, embodiments of systems and methods for tuning seed layer hardness in components of magnetic recording systems such as a slider or a magnetic medium are illustrated. The systems and methods employ a novel system or process, termed a co-deposition system/process, developed to re-engineer the seed layer of the HOC film to further improve its wear and corrosion durability. The co-deposition systems and processes effectively inject sp³ C bonds into the seed layer using a seed material source and a filtered cathodic arc (FCA) carbon (C) source. The seed material source and the FCA-C source are applied substantially at the same time in a deposition system such as a vacuum deposition system.

The sp³ C bond is the bond that forms diamond, which is the hardest among all materials known. Data collected shows that the new systems and processes can be employed to tune the hardness of the co-deposited seed layer effec-

tively within a wide range that virtually doubles that of a seed layer deposited in the conventional way. The harder seed layer will help in enhancing wear and corrosion performance, therefore providing a potential to further reduce head over coat thickness for improved electro-magnetic gain of the read-write head, among other benefits.

The terms "above," "below," and "between" as used herein refer to a relative position of one layer with respect to other layers. As such, one layer deposited or disposed above or below another layer may be directly in contact with the other layer or may have one or more intervening layers. Moreover, one layer deposited or disposed between layers may be directly in contact with the layers or may have one or more intervening layers.

It shall be appreciated by those skilled in the art in view of the present disclosure that although various exemplary fabrication methods are discussed herein with reference to magnetic recording disks, the methods, with or without some modifications, may be used for fabricating other types of recording disks, for example, optical recording disks such as a compact disc (CD) and a digital-versatile-disk (DVD), or magneto-optical recording disks, or ferroelectric data storage devices.

FIG. 1 is a schematic top view of a two source vacuum deposition system 100 for tuning the seed layer hardness of sliders arranged in row bars on a rotatable substrate/pallet 102 in accordance with one embodiment of the invention. The two source vacuum deposition system 100 includes a seed material source 104 configured to deposit one or more seed materials on the substrate/pallet 102 at a first angle 104a measured with respect to a top surface of the substrate/pallet 102. In several embodiments, the top surface of the substrate/pallet 102 reflects a top surface of the row bars mounted within the substrate/pallet 102. The two source vacuum deposition system 100 also includes a carbon material source ("FCA-C") 106 configured to deposit or inject sp³ carbon bonds on the substrate/pallet 102 at a second angle 106a measured with respect to a top surface of the substrate/pallet 102.

In operation, the substrate/pallet 102 is configured to be rotated by a drive motor (not shown) to achieve optimal deposition uniformity. The seed material source 104 and the carbon material source 106 are configured to be applied simultaneously or about simultaneously and for about the same duration. In related art processes for forming a seed layer, a seed source is turned on first and turned off when a desired thickness for the seed layer has been achieved. Then, after the seed source has been turned off, the FCA-C source is turned on. As such, the seed source and FCA-C source are not applied simultaneously in the related art processes. In contrast, for the two source vacuum deposition system 100 of FIG. 1, the seed source 104 and the FCA-C source 106 are applied substantially simultaneously. At the same time, the deposition rates of the materials deposited by the seed source 104 and the FCA-C source 106 can be adjusted independently. As a result, the hardness of the seed layer (e.g., a composite seed layer) is a function of a deposition rate ratio between the rate of seed material deposition and the rate of FCA-C deposition.

In some embodiments, the substrate 102 can be a magnetic medium for a magnetic recording system rather than the sliders arranged in row bars. In several embodiments, the seed layer material can be TiN, TiC, Si₃N₄, Ti_XSi₃N₄, Cr_XSi_YN_Z, where X, Y, and Z are non-zero positive integers, and/or other suitable seed layer materials. In a number of embodiments, the hardness of the seed layer resulting from the deposition of the seed layer material and the carbon

material is proportional to an amount of the carbon material deposited, and more specifically, the amount of sp³ bonds deposited or injected. In one embodiment, an atomic percent of the carbon material is greater than an atomic percent of the seed layer material to ensure a preselected degree of seed layer hardness. In several embodiments, the co-deposition process is performed such that the seed layer has a preselected number of the sp³ carbon bonds.

In some embodiments, the first angle 104a for the seed layer material, measured with respect to the top surface of the substrate 102, is in a range from about 35 degrees to about 55 degrees. In another embodiment, the first angle 104a is in a range from about 40 degrees to about 50 degrees. In some embodiments, the second angle 106a for the carbon material, measured with respect to the top surface of the substrate, is in a range from about 75 degrees to about 105 degrees. In another embodiment, the second angle 106a is in a range from about 80 degrees to about 100 degrees. In the embodiment of FIG. 1, the seed material source 104 and the carbon material (FCA-C) source 106 are shown as having particular angles for the first angle 104a and the second angle 106a. In other embodiments, the first angle 104a and the second angle 106a can have other suitable values.

In a number of embodiments, the substrate is rotated at a preselected speed during the deposition of the seed layer material and the carbon material to achieve a preselected degree of deposition uniformity. In one such embodiment, the preselected speed is in a range of about 15 rpm to about 30 rpm.

In several embodiments, the seed material source 104 is a radio frequency (RF) magnetron, and the carbon material (FCA-C) source 106 is a filtered cathodic arc. In one such embodiment, the arc current of the FCA-C source 106 is about 20 to 100 amps, and the power level of the seed source 104 is set to about 100 to 350 watts. In other embodiments, the arc current and power levels can be set to other suitable values. In other embodiments, the seed material source 104 can be a ion beam sputter source and/or a chemical vapor deposition (CVD) source. In other embodiments, another vacuum deposition system configured with a carbon source and a seed source with suitable alignment capabilities can be used. In such case, the alternative vacuum deposition system can also include a pre-clean etch capability.

In some embodiments, the system further includes a sputter target for the seed layer material where a distance between the sputter target and the substrate is about 25 mm to about 65 mm. In one embodiment, the system includes a vacuum deposition chamber containing the substrate 102, where the vacuum deposition chamber has a preselected pressure in a range of about 0.25 mTorr to about 1.25 mTorr. In one embodiment, the seed material source 104 and the carbon material (FCA-C) source 106 are configured to deposit the seed layer material and the carbon material, respectively, simultaneously for a duration of about 5 seconds to about 25 seconds.

FIG. 2 is a schematic top view of a three source vacuum deposition system 200 for tuning the seed layer hardness of sliders arranged in row bars 205 on a rotatable substrate/pallet 202 in accordance with one embodiment of the invention. The three source vacuum deposition system 200 includes a filtered cathodic vacuum arc carbon material source ("FCVA-C") 206 configured to deposit or inject sp³ carbon bonds on a top surface (e.g., air bearing surface) of row bars 205 disposed on a substrate/pallet 202 at a second angle 206a measured with respect to a top surface of the row bars 205. The three source vacuum deposition system 200

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further includes a first seed material source **204-1** (e.g., RF magnetron) configured to deposit a first seed material of Si_3N_4 on a top surface of the row bars **205** at a first angle **204-1a** measured with respect to a top surface of the row bars **205**. The three source vacuum deposition system **200** further includes a second seed material source (e.g., filtered cathodic vacuum arc or "FCVA-Ti/TiN") **204-2** configured to deposit a second seed material of Ti/TiN on the row bars **205** at a third angle **204-2a** measured with respect to a top surface of the row bars **205**.

In FIG. 2, the first angle **204-1a** for the first seed material is about 135 degrees. The second angle **206a** for the carbon material is about 90 degrees. The third angle **204-2a** for the second seed material is about 45 degrees. In other embodiments, the first, second and third angles can have other suitable values. For example, in some embodiments, the first angle **204-1a** is in a range from about 125 degrees to about 145 degrees. In some embodiments, the second angle **206a** is in a range from about 75 degrees to about 105 degrees. In some embodiments, the third angle **204-2a** is in a range from about 35 degrees to about 55 degrees.

The three source vacuum deposition system **200** also includes a vacuum chamber **208** that encloses or substantially encloses the substrate **202** and row bars **205** disposed thereon. The carbon material source ("FCVA-C") **206**, the first seed material source **204-1**, and the second seed material source ("FCVA-Ti/TiN") **204-2** are each mounted to an exterior surface of the vacuum chamber **208**. In FIG. 2, a number of specific angles are shown for sides/walls of the vacuum chamber **208**. In other embodiments, however, other suitable angles can be used.

In operation, the substrate/pallet **202** is configured to be rotated by a drive motor (not shown) to achieve optimal deposition uniformity. The carbon material source **206** and one or both of the first seed material source **204-1** and the second seed material source **204-2** are configured to be applied about simultaneously and for about the same duration. The deposition rates of the materials deposited by the seed sources (**204-1**, **204-2**) and the carbon source **206** can be adjusted independently. As a result, the hardness of the seed layer is a function of a deposition rate ratio between the rate of seed material deposition(s) and the rate of carbon deposition.

In some embodiments, the substrate **202** can be replaced with a magnetic medium for a magnetic recording system rather than the sliders arranged in row bars. In several embodiments, the seed layer material(s) can be Ti, TiN, TiC, Si_3N_4 , $\text{Ti}_X\text{Si}_3\text{N}_4$, $\text{Cr}_X\text{Si}_3\text{N}_Z$, where X, Y, and Z are non-zero positive integers, and/or other suitable seed layer materials. In a number of embodiments, the hardness of the seed layer resulting from the deposition of the seed layer material(s) and the carbon material is proportional to the amount of the carbon material deposited, and more specifically, the amount of sp³ bonds deposited or injected.

In a number of embodiments, the substrate is rotated at a preselected speed during the deposition of the seed layer material(s) and the carbon material to achieve a preselected degree of deposition uniformity. In one such embodiment, the preselected speed is in a range of about 15 rpm to about 30 rpm.

In several embodiments, the first seed material source **204-1** is a radio frequency (RF) magnetron, and the carbon material source **206** and the second seed material source **204-2** are FCA or FCVA deposition devices. In some embodiments, the system further includes a sputter target for the seed layer material(s) where a distance between the sputter target and the substrate is about 25 mm to about 65

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mm. In one embodiment, the vacuum deposition chamber **208** has a preselected pressure in a range of about 0.25 mTorr to about 1.25 mTorr. In one embodiment, the seed material source(s) (**204-1**, **204-2**) and the carbon material (FCVA-C) source **206** are configured to deposit the seed layer material(s) and the carbon material, respectively, simultaneously for a duration of about 5 seconds to about 25 seconds.

FIG. 3 is a perspective view of a rotatable substrate/pallet **302** with multiple row bar carriers **303** that can be used in the vacuum deposition systems of FIG. 1 or FIG. 2. More specifically, five row bar carriers **303** are mounted to the substrate/pallet **302**. Each carrier **303** has a rectangular shape with a length of about 2.4 inches and a width of about 2 inches, though other suitable dimensions will work as well. Each carrier **303** includes a number of slots configured to receive the row bars **305**. Each carrier **303** is configured to retain about 40 to 50 row bars **305**, though other suitable numbers of row bars can be retained as well. In the embodiment illustrated in FIG. 3, the pallet **302** is configured to support and retain 5 carriers **303**. In other embodiments, the pallet **302** can be configured to support and retain more than, or fewer than, 5 carriers **303**.

FIG. 4 is an expanded perspective view of the row bar carrier **303** of the rotatable substrate/pallet **302** of FIG. 3. As can be seen in FIG. 4, the carrier **303** contains a number of row bars **305** arranged such that a top exposed surface of the row bars corresponds to the air bearing surface (ABS) of the sliders disposed in the row bars. In several embodiments, about 50 to 60 sliders are disposed in a given row bar.

FIG. 5 is a schematic perspective view of a slider **415** with a seed layer **415a** having been deposited along an air bearing surface thereof using a co-deposition system having both a seed layer material source and a carbon material source in accordance with one embodiment of the invention. The seed layer **415a** can be deposited using one or both of the deposition systems described above for FIG. 1 and FIG. 2.

FIG. 6 is a top schematic view of a disk drive **400** including the slider **415** of FIG. 5 in accordance with one embodiment of the invention. Disk drive **400** may include one or more disks **425** to store data. Disk **425** resides on a spindle assembly **420** that is mounted to drive housing **405**. Data may be stored along tracks in the magnetic recording layer of disk **425**. The reading and writing of data is accomplished with head/slider **415** that has both read and write elements. The write element is used to alter the properties of the magnetic recording layer of disk **425**. In one embodiment, head/slider **415** may have magneto-resistive (MR), or giant magneto-resistive (GMR) elements. In an alternative embodiment, head/slider **415** may be another type of head, for example, an inductive read/write head or a Hall effect head.

In operation, a spindle motor (not shown) rotates spindle assembly **420**, and thereby rotates disk **425** to position head/slider **415** at a particular location along a desired disk track. The position of head/slider **415** relative to disk **425** may be controlled by position control circuitry **410**. The use of head/slider **415** fabricated in the manners discussed above may improve the performance of magnetic recording in a disk drive configured for heat assisted magnetic recording (HAMR), energy assisted magnetic recording (EAMR), perpendicular magnetic recording (PMR) or microwave assisted magnetic recording (MAMR). More specifically, a harder seed layer should enhance wear and corrosion performance, therefore providing a potential to further reduce head over coat thickness for improved electro-magnetic gain of the read-write head.

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FIG. 7 is a graph 500 of seed layer hardness 502 versus a deposition rate ratio 504 of the seed layer material deposition rate to the carbon material deposition rate in accordance with one embodiment of the invention. As can be seen in FIG. 7, when the deposition rate of carbon (FCA-C) is relatively low at 0.0, the seed layer hardness is relatively low (e.g., about 26 giga Pascal or GPa). However, when the deposition rate of carbon (FCA-C) is relatively high at 1.0, the seed layer hardness is relatively high (e.g., about 57 GPa or more than twice the hardness without the injected carbon). Thus, FIG. 7 shows that the seed layer hardness is dependent on the deposition rate ratio of the seed layer material to the carbon material. In addition, FIG. 7 shows that the seed layer hardness is proportional to the amount of carbon deposited.

FIG. 8 is a flowchart of a co-deposition process 600 for tuning seed layer hardness in components of a magnetic recording system such as a slider or a magnetic medium in accordance with one embodiment of the invention. In particular embodiments, process 600 can be used in conjunction with the deposition systems of FIGS. 1 and/or 2 described above. The process first provides (602) a substrate that is a component of a magnetic recording system. The component can be a slider (e.g., disposed in a row bar) or a magnetic medium. The process then deposits (604) a seed layer material on a portion of a top surface of the substrate at a first angle. In some embodiments, a second seed layer material is deposited on the portion of the top surface at a third angle. The process also deposits (606) a carbon material including sp³ carbon bonds on the portion of the top surface at a second angle not equal to the first angle, where the depositing the seed layer material (604) and the depositing the carbon material (606) on the top surface of the substrate are performed simultaneously or about simultaneously.

In several embodiments, the process also includes rotating the substrate at a preselected speed during the depositing the seed layer material and the depositing the carbon material. In a number of embodiments, the process also includes forming magnetic transducers in the substrate, dicing the substrate into row bars, depositing the seed layer material on an ABS of the row bars at the first angle, depositing (e.g., during the seed layer material deposition) the carbon material including the sp³ carbon bonds on the ABS of the row bars at the second angle, and then dicing the row bars to form sliders.

In one embodiment, the process can perform the sequence of actions in a different order. In another embodiment, the process can skip one or more of the actions. In other

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embodiments, one or more of the actions are performed simultaneously. In some embodiments, additional actions can be performed.

While the above description contains many specific embodiments of the invention, these should not be construed as limitations on the scope of the invention, but rather as examples of specific embodiments thereof. Accordingly, the scope of the invention should be determined not by the embodiments illustrated, but by the appended claims and their equivalents.

What is claimed is:

1. A slider for a magnetic recording system, the slider comprising:

an air bearing surface (ABS) comprising a seed layer deposited using a co-deposition process comprising deposition of a seed layer material on the ABS at a first angle and deposition of a carbon material comprising sp³ carbon bonds on the ABS at a second angle not equal to the first angle,

wherein the deposition of the seed layer material and the deposition of the carbon material are performed simultaneously, and

wherein the seed layer comprises a preselected number of the sp³ carbon bonds.

2. The slider of claim 1, wherein the seed layer material comprises a material selected from the group consisting of TiN, TiC, Si₃N₄, Ti_XSi₃N₄, Cr_XSi₃N_Z, and combinations thereof, where X, Y, and Z are non-zero positive integers.

3. The slider of claim 1, wherein a hardness of the seed layer resulting from the deposition of the seed layer material and the carbon material is proportional to an amount of the carbon material deposited.

4. The slider of claim 1:

wherein the first angle for the seed layer material is measured with respect to the ABS and is in a range from about 35 degrees to about 55 degrees; and

wherein the second angle for the carbon material is measured with respect to the ABS and is in a range from about 75 degrees to about 105 degrees.

5. The slider of claim 1:

wherein the seed layer material is deposited using a radio frequency (RF) magnetron; and

wherein the carbon material is deposited using a filtered cathodic arc.

6. The slider of claim 1, wherein an atomic percent of the carbon material is greater than an atomic percent of the seed layer material.

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